Lat 40.01598 Lon -120.99294

Forest Health Protection

Pacific Southwest Region

Northeastern California Shared Service Area

Date: April 18, 2016
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To: District Ranger, Mt. Hough Ranger District, Plumas National Forest

Subject: Evaluation of stand conditions with respect to forest insects and diseases in the Butterfly Twain Fuels Reduction and Landscape Restoration Project (FHP Report NE16-05)

Summary

At the request of Maurice Huynh, Silviculturist, Mt. Hough Ranger District, Danny Cluck, Forest Health Protection (FHP) entomologist visited the Butterfly Twain Fuels Reduction and Landscape Restoration Project on March 31, 2016. The objective of this visit was to evaluate current stand conditions, determine the impacts of forest insects and diseases on management objectives and discuss proposed alternatives. Recommendations provided in this report will assist in the formulation of silvicultural prescriptions aimed at reducing stand density and increasing resiliency to disturbance events such as fire, insects and diseases.

Key findings:

- Several native forest insects and diseases were observed during the site visit contributing to tree mortality including bark beetles and root disease.
- Aerial detection surveys in 2015, which provided a project-wide assessment of current conditions, recorded elevated levels of tree mortality in many locations.
- Mortality was highest for white fir, followed by ponderosa and sugar pine.
- Overstocking is putting many stands at risk to high levels of bark beetle-caused tree mortality during periods of drought. Many of these same stands are also at risk to high severity wildfire.
- Thinning and prescribed fire are proposed throughout the project area to reduce stocking levels, reduce surface and ladder fuels and change forest composition to favor more drought tolerant species. Specific recommendations are provided in this evaluation.

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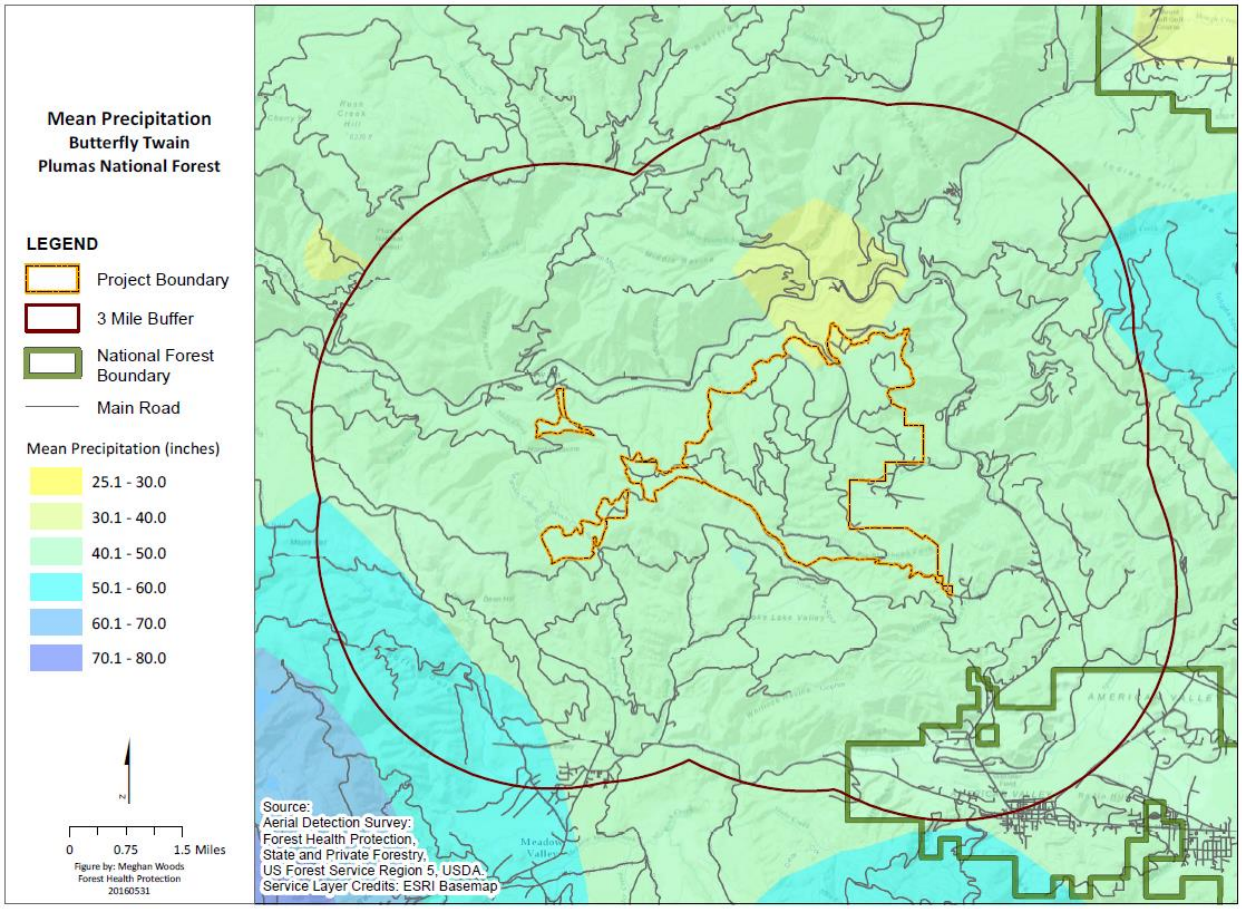
Description of the project area

The Butterfly Twain project is located approximately 4 miles northwest of Quincy, CA (40.015984 and 120.992941). The elevation of the project area ranges from 3,300 to 4,600 feet with average annual precipitation ranging from 30 – 50 inches. Most of the project area receives greater than 40" of average annual precipitation (Figure 1). Existing forest type is predominantly Sierra Nevada mixed conifer with ponderosa pine (*Pinus ponderosa*), Douglas-fir (*Psuedotsuga menziesii*), sugar pine (*Pinus lambertiana*), incense cedar (*Calocedrus decurrens*), white fir (*Abies concolor*) and black oak (*Quercus kelloggii*). Ponderosa pine, sugar pine, incense cedar and Douglas-fir make up most of the overstory while the understory consists of white fir, incense cedar and Douglas-fir. Nearly all stands are overly dense with scattered old growth, high numbers of smaller sawlog sized trees (10 – 20" dbh) and an abundance of small diameter (< 10" dbh) trees.

Figure 1. Mean annual precipitation for the Butterfly Twain project area.



Management objectives

The management objectives for this project are reduce stand density, reduce surface and ladder fuels and to protect existing wildlife habitat areas and adjacent communities. Density and fuels reduction would occur with a variable thinning strategy. Variable thinning would reduce stand density and change species composition to a more sustainable condition by removing trees from all size classes (< 30" dbh) outside of designated wildlife habitat areas, creating gaps and clumps, and removing competition from around old growth trees. Based on current stand

conditions, most of the material removed during thinning would be in the < 20" dbh range. This type of treatment would begin to move these stands to a more resilient condition that is consistent with Regional ecosystem restoration goals. Within designated wildlife habitat areas (California spotted owl protected activity centers), thinning would be restricted to the removal of trees less than 6" in diameter outside of the wildland urban interface (WUI) zone and less than 10" in diameter within the WUI.

Forest insect and disease conditions

Tree mortality attributable to forest insects and/or diseases is occurring at low levels in most of the areas covered during this evaluation. However, a very large, old growth sugar pine was found to be mass attacked by mountain pine beetle (*Dendroctonus ponderosae*) suggesting that some trees are currently under severe moisture stress from inter-tree competition and the ongoing drought. White pine blister rust (*Cronartium ribicola*) was also observed on a few sugar pines but does not appear to be common within the project area.

A large area of ponderosa pine mortality, caused by the western pine beetle (*Dendroctonus brevicomis*), was observed within the Butterfly Valley Botanical Area. One group kill in this area consisted of more than 20 larger diameter pines. This suggests that western pine beetle populations are high and likely increasing within the project area.

White fir mortality caused by the fir engraver beetle (*Scolytus ventralis*) was observed in a few locations. One location appeared to be associated with Heterobasidion root disease, caused by *Heterobasidion occidentale.*

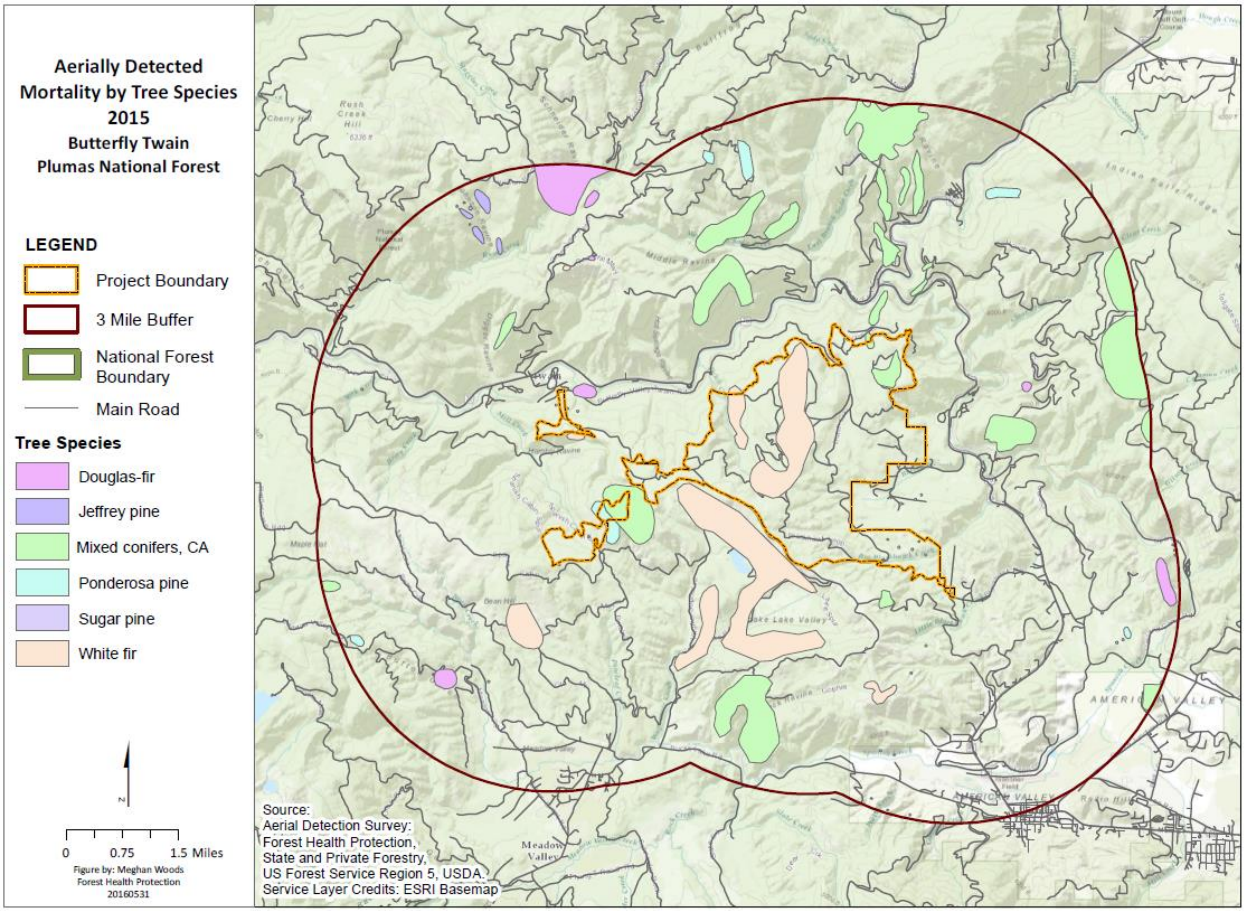
Evidence of older bark beetle-caused tree mortality was observed throughout the area (snags and downed logs). This included mountain pine beetle attacks on smaller diameter (8 – 12" dbh) ponderosa pine, western pine beetle attacks on large diameter (>15" dbh) ponderosa pine and fir engraver beetle attacks on white fir of all sizes. Most of this older mortality likely occurred during the 1987 – 1992 drought.

Red ring rot (*Porodaedalea pini*) was found on one Douglas-fir and a suspected bacterial gall/canker was observed on several Douglas-fir but were not causing any issues.

Aerial detection surveys conducted by Region 5 Forest Health Monitoring have detected low levels of tree mortality caused by bark beetles nearly every year from 2008 to 2014 within and adjacent to the project area. Most of this mortality was scattered and caused by the same bark beetle species observed during this evaluation (mountain pine beetle, western pine beetle and fir engraver beetle). In addition, the aerial surveys identified Douglas-fir mortality caused by flatheaded fir borer (*Phaenops drummondi*) in 2012 and Douglas-fir beetle (*Dendroctonus pseudotsugae*) in 2013.

The 2015 aerial survey documented a substantial increase in tree mortality within and adjacent to the project area consistent with the ongoing drought and overly dense stand conditions (Figure 2). Most tree mortality was recorded as white fir followed by mixed conifers, Douglas-fir and ponderosa pine.

Figure 2. Areas with mapped tree mortality in 2015 within and adjacent to the Butterfly Twain project area.



Stand conditions and mortality related to recent and future climate trends

Most of the stands within the Butterfly Twain project appear to be at or above "normal" stocking levels and have exhibited an elevated level of tree mortality caused by bark beetles during and after periods of drought (Figure 3 and Table 1). This mortality combined with high stand density has resulted in heavy fuel loading in many areas and a corresponding increase in potential fire behavior.

These dense stand conditions with high canopy closure also appear to have greatly reduced the amount of ponderosa pine regeneration within the project area, shifting stand composition to more shade tolerant tree species. The distribution and species composition of old growth trees within portions of the project area suggests that these stands were more open in the past, maintained by frequent low severity fire.

Current tree mortality attributable to insects and/or pathogens is patchy within the project area and at generally low levels. However, aerial detection surveys within and adjacent to the project area have identified a sharp increase in mortality during the past year (Table 1). Elevated levels of tree mortality in this area, as well as in the rest of the Sierra Nevada range, are strongly associated with periods of below normal precipitation and high stand density. Successive dry years can exacerbate unhealthy stand conditions, such as those that exist within the Butterfly Valley Project; resulting in higher levels of bark beetle-caused tree mortality. The Palmer

Hydrologic Drought Index is also included in Table 1 to show the relationship between drought and tree mortality.

Table 1. Acres with mortality, estimated dead trees per acre and estimated total # of dead trees from R5 Aerial Detection Surveys and Palmer Hydrologic Drought Index (PHDI) (average of CA Divisions 2 and 3[1]) by water year (Oct-Sept) within and adjacent to the Butterfly Twain area.

Year	Acres	Dead Trees/Acre	Total # of Dead Trees	PHDI[2]
2015	4,856	2.3	11,050	-3.34
2014	102	1.6	158	-3.56
2013	165	1.7	286	-2.16
2012	148	2.1	310	-0.59
2011	695	1.2	823	2.78
2010	511	1.3	656	-0.14
2009	176	6.0	1,060	-2.98
2008	6	4.2	26	-3.16
2007	2	19.2	30	-3.17
2006	5	2.4	12	2.40

[1] California Divisions 2 and 3 encompass most of northeastern California. Butterfly Twain is on the border between these two zones.
[2] PHDI values ranging from -2.00 to -2.99 are considered moderate drought conditions. Severe drought conditions range from -3.00 to -3.99 and extreme drought conditions are below -4.00.

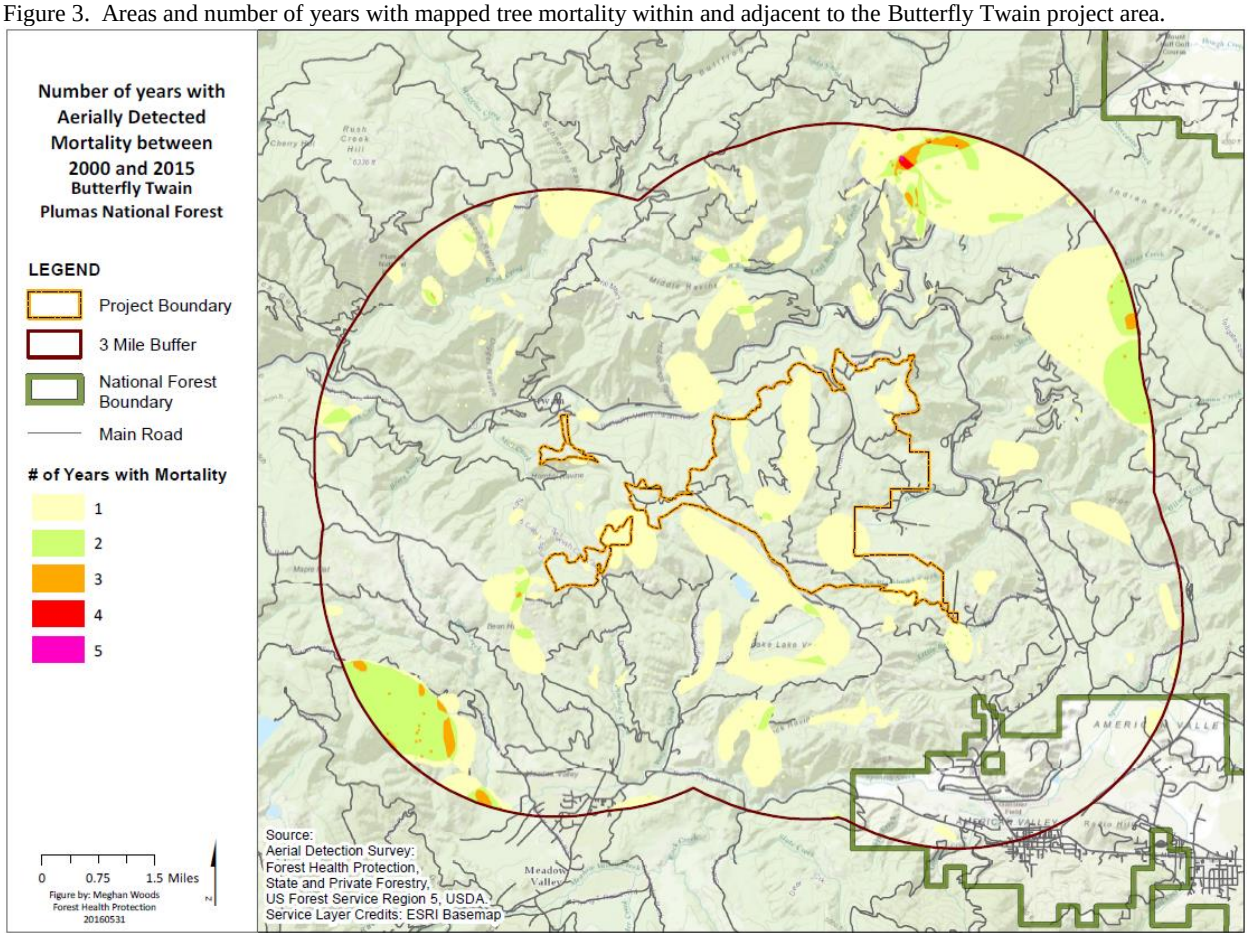
Mapping by the ADS over the past 10 years within and adjacent to the Butterfly Twain reveals only a few areas where bark beetle-caused tree mortality has been a chronic problem. However, the dramatic increase in tree mortality mapped in 2015 is a clear sign that these stands are vulnerable to drought and that high levels of tree mortality could occur if the current drought continues (Figure 2).

Figure 3 also depicts many areas where no mortality was mapped during the past 10 years. This is not uncommon for Sierra mixed conifer stands that typically receive >40" of precipitation per year. However, many stands do exist within this "mortality free" zone that are at a high risk to bark beetle-caused tree mortality due to overstocked conditions and could experience unacceptable levels of tree mortality during prolonged and/or severe drought. For example, the current exceptional drought in the south Sierra Nevada range has resulted in high levels of mortality in mixed conifer stands similar to the Butterfly Twain project stands. Anticipating future drought events and reducing tree density to levels that are more resilient and sustainable should reduce the risk of unacceptable levels of tree mortality within the Butterfly Twain project area.

Predicted climate change is likely to impact trees growing in the Butterfly Twain area over the next 100 years. Although no Plumas National Forest specific climate change models are available at this time, there is a general consensus among California models that summers will be drier than they are currently. This prediction is based on the forecasted rise in mean minimum and maximum temperatures and remains consistent regardless of future levels of annual precipitation (K. Merriam and H. Safford, *A summary of current trends and probable future trends in climate and climate-driven processes in the Sierra Cascade Province, including the Plumas, Modoc, and Lassen National Forests*. The risk of bark beetle-caused tree mortality will likely increase for all conifer species under this scenario, especially drought intolerant white fir and overly dense stands of ponderosa pine. Improving the resilience of stands to future

disturbance events through density, size class and species composition management will be critical to maintaining a healthy forested landscape.

Figure 3. Areas and number of years with mapped tree mortality within and adjacent to the Butterfly Twain project area.



Considerations for thinning treatments

Most of the thinning treatments proposed by the District should reduce stand density to a level that significantly lowers the risk of bark beetle caused mortality. In most cases, thinning to a relative density of 25 - 40% (relative to the maximum Stand Density Index, or SDI) for a specific conifer species or for a weighted composition of conifer species will effectively reduce competition for limited water and nutrients and reduce the susceptibility to future bark beetle-caused tree mortality.

Some stands on south facing slopes and ridge tops within the Butterfly Twain project area contain scattered large diameter ponderosa and sugar pine. Thinning treatments that improve growing conditions for these more shade intolerant species, such as removing a large percentage of the white fir and Douglas-fir basal area around these trees, would increase their health and vigor, create opportunities for their successful regeneration and improve overall resiliency to disturbance agents (insects, disease, drought and fire). Removing competing trees from the base of large diameter pines combined with stand level thinning has resulted in a measured increase in annual increment growth in old growth ponderosa and Jeffrey pine on the Lassen National Forest (FHP unpublished data).

Stocking for most of the pure ponderosa pine and ponderosa pine/black oak stands appears to be at levels above what is considered sustainable. As a result, elevated levels of western pine beetle-caused tree mortality can be expected during prolonged drought. The District should consider using the bark beetle limiting SDI of 365 as a basis for thinning prescriptions. SDI 365 is considered the upper management zone above which bark beetle outbreaks are likely to occur and SDI 230 is considered the threshold for the zone of imminent bark beetle caused mortality. Within this zone, endemic populations kill a few trees but net growth is still positive (Oliver 1995). Planning thinning treatments that result in stocking levels well below SDI 230 would greatly reduce the risk of bark beetle-caused mortality in these areas.

When planning thinning treatments, it should be recognized that the target stand density is an average to be applied across the landscape and some variability may be desired. Individual high value trees, such as mature pines and black oaks, should benefit by having the stocking around them reduced to lower levels. Areas of pure or nearly pure ponderosa pine would also benefit from lower stocking levels as well as an increase in species diversity. Allowing for denser tree spacing and pockets of higher canopy cover may be desirable around potential wildlife trees, such as forked and/or broken-topped trees, or on more mesic north-facing slopes. Incorporating the concepts of GTR 220 will address many of these issues and be consistent with Regional ecosystem restoration goals. Many of these methods are also consistent with past FHP recommendations for thinning in mixed conifer stands and their use is supported for the Butterfly Twain project.

The diameter limits established for cutting trees within wildlife habitat areas (<6" dbh outside of WUI and <10" dbh within WUI) may achieve short-term fuel reduction objectives but may not achieve a sufficient density reduction to lessen the risk of bark beetle-caused mortality during droughts. Excessive tree mortality during future droughts could reduce the effectiveness of fuel treatments as dead trees fall to the ground. It may also reduce habitat suitability due to a reduction in canopy cover. Thoroughly treating stands adjacent to these wildlife habitat areas to reduce the risk of high severity wildfire and the risk to bark beetle-caused mortality will be vital to maintaining heterogeneity on the landscape and provide current and future wildlife habitat.

It is recommended that a registered borate compound be applied to all freshly cut conifer stumps >14" in diameter to reduce the chance of creating new infection centers of *Heterobasidion irregulare* and *H. occidentale* formerly referred to as P-type and S-type annosus root disease, through harvest activity.

Sugar pine should be retained as much as possible during any thinning operation in order to preserve genetic diversity, especially white pine blister rust (*Cronartium ribicola*) resistant individuals. An exception to this would be thinning suppressed trees within pure sugar pine groups to reduce inter-tree competition. White pine blister rust, a non-native pathogen, has continued to weaken and kill this species over most of its range since its introduction into the Pacific Northwest in 1910. Identification and protection of local rust resistant trees for seed collection, if not already occurring, will aid in the future planting of rust resistant seedlings. Planting selected openings created through thinning operations with rust resistant stock would help insure this species persists in the area.

Considerations for Rx fire

If prescribed fire is used as a follow-up treatment to stand thinning, it may result in unacceptable levels of tree mortality; depending on management objectives. This mortality most often occurs as a direct result of cambium or crown injury to individual trees during the fire. Mature ponderosa, Jeffrey and especially sugar pines are susceptible to lethal basal cambium damage during prescribed burns from the heat that develops in the deep duff and litter that accumulates at their bases. These duff mounds typically burn at a slow rate with lethal temperatures, causing severe injury to the cambium which girdles the trees. To protect individual high-value large diameter pine from lethal cambium damage, raking the duff away from the bases of these trees before burning (within 24" of the bole and down to mineral soil) is recommended.

Potential for funding thought the Western Bark Beetle Program

Forest Health Protection may be able to assist with funding, including NEPA activities, for thinning and removing green material from overstocked areas within the Butterfly Twain project area. Thinning treatments that reduce stand density sufficient to lower the risk to bark beetle-caused mortality would meet the minimum requirements for Western Bark Beetle Program funding and would be supported by this evaluation. If you are interested in this competitive funding please contact me for assistance in developing and submitting a proposal.

If you have any questions regarding this report and/or need additional information please contact Danny Cluck at 530-252-6431.

/s/ Danny Cluck

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Insect and Disease Information

Fir Engraver

The fir engraver attacks red and white fir in California. Fir engraver adults and developing broods kill true firs by mining the cambium, phloem, and outer sapwood of the bole, thereby girdling the tree. Trees greater that 4" in diameter are attacked and often killed in a single season. Many trees, weakened through successive attacks, die slowly over a period of years. Others may survive attack as evidenced by old spike-topped fir and trees with individual branch mortality. Although many other species of bark beetles cannot develop successful broods without killing the tree, the fir engraver beetle is able to attack and establish broods when only a portion of the cambium area has been killed.

Evidence of Attack

Fir engravers bore entrance holes along the main stem, usually in areas that are > 4" in diameter. Reddish-brown or white boring dust may be seen along the trunk in bark crevices and in spider webs. Some pitch streamers may be indicative of fir engraver attacks; however, true firs are known to stream pitch for various reasons and there is not clear evidence that pitch streamers indicate subsequent tree mortality or successful attack. Resin canals and pockets in the cortex of the bark are part of the trees defense mechanism. Beetle galleries that contact these structures almost always fail to produce larval galleries as the adults invariably abandon the attack. Pitch tubes, often formed when bark beetles attack pine, are not produced on firs.

Adults excavate horizontal galleries that engrave the sapwood; the larval galleries extend at right angles along the grain. Attacks in the crown may girdle branches resulting in individual branch mortality or "flagging". Numerous attacks over part or the entire bole may kill the upper portion of the crown or the entire tree. A healthy tree can recover if sufficient areas of cambium remain and top-killed trees can produce new leaders. The fir engraver is frequently associated with the roundheaded fir borer and the fir flatheaded borer.

Life Stages and Development

In the summer, adults emerge and attack new host trees. The female enters the tree first followed by the male. Eggs are laid in niches on either side of the gallery. Adult beetles carry the brown staining fungi, *Trichosporium symbioticum*, into the tree that causes a yellowish-brown discoloration around the gallery. The larvae mine straight up and down, perpendicular to the egg gallery. Winter is commonly spent in the larval stage, with pupation occurring in early spring. In most locations, the fir engraver completes its life cycle in 1 year, however at higher elevations 2 years may be required.

Conditions Affecting Outbreaks

Fir engravers bore into any member of the host species on which they land but establish successful galleries only in those that have little or no resistance to attack. Populations of less aggressive species like fir engraver are likely to wax and wane in direct relationship to the stresses of their hosts. Drought conditions often result in widespread fir mortality; however, attempting to determine when outbreaks will occur is difficult. Lowered resistance of trees appears to be a contributing factor. Overstocking and the increased presence of fir on sites that were once occupied by pine species may also contribute to higher than normal levels of fir mortality. Several insect predators, parasites and woodpeckers are commonly associated with the fir engraver and may help in control of populations at endemic levels.

Western Pine Beetle

The western pine beetle, *Dendroctonus brevicomis*, has been intensivly studied and has proven to be an important factor in the ecology and management of ponderosa pine thoughout the range of the host

species (Miller and Keen 1960). This insect breeds in the main bole of living ponderosa pine larger than about 8 inches DBH. Normally it breeds in trees weakened by drought, overstocking, root disease, dwarf mistletoe or fire. Adult beetles emerge and attack trees continuously from spring through fall. Depending on the latidude and elevation, there can be from one to four generations per year.

Evidence of Attack

Initial attacks are made about mid-bole and subsequent attacks fill in above and below. Pitch tubes are formed on the tree trunk around the entry holes. Successful pitch tubes are red-brown masses of resin and boring dust. Relativly few, widely scattered white pitch tubes usually indicate that the attacks were not successful and that the tree should survive. Pheremones released during a successful attack attract other conspecifics. Attracted beetles may then spill over into nearby apparently healthy trees and overwhelm the tree with sheer numbers.

Life Stages and Development

These beetles pass thorugh the egg, larval, pupal and adult stages during a life cycle that varies in length dependent primarily on temperature. Adults bore a sinuous gallery pattern in the phloem and the female lays eggs in niches along the sides of the gallery. The larvae are small white grubs that first feed in the phloem then mine into the middle bark where they complete most of their development. Bluestain fungi inoculates the tree during successful attacks, blocking trachids and vessicles which contribute to the rapid tree mortality associated with bark beetle attacks.

Conditions affecting Outbreaks

Outbreaks of western pine beetle have been observed, and surveys made, in pine regions of the Westsince 1899 (Hopkins 1899; cited in Miller and Keen 1960). An insect survey completed in 1917 in northern California indicated that over 25 million board feet of pine timber had been killed by bark beetles.Information from surveys conducted in the 1930's indicated enormous losses attributed to the western pine beetle around that time. During the 1930's outbreak, most of the mortality occurred in stands of mature or overmature trees of poor vigor (Miller and Keen 1960). Group kills do not typically continue to increase in size though successive beetle generation as is typical with Mountain Pine Beetle and Jeffreay Pine Beetle. Rather, observations indicate that emerging beetles tend to leave the group kill area to initiate new attacks elsewhere.

The availability of suitable host material is a key condition influencing western pine beetle outbreaks. In northeastern California, drought stress may be the key condition influencing western pine beetle outbreaks. When healthy trees undergo a sudden and sever moisture stress populations of western pine beetle are likely to increase. Healthy trees ordinarily produce abundant resin, which pitch out attacking beetles, but when deprived of moisture, stressed trees cannot produce sufficient resin to resist the attack. Any condition that results in excessive demand for moisture, such as inter-tree completion, competing vegetation, or protracted drought periods; or any condition that reduces the ability of the roots to supply water to the tree, such as mechanical damage, root disease or soil compaction, can cause moisture stress and increase susceptibility to attack by the western pine beetle. Woodpeckers, predacious beetles, and low temperatures act as natural control agents when beetle populations are low (endemic populations).

Mountain pine beetle

The mountain pine beetle, *Dendroctonus ponderosae*, attacks the bole of ponderosa, lodgepole, sugar and western white pines larger than about 8 inches dbh. Extensive infestations have occurred in mature

lodgepole pine forests. Group killing often occurs in mature forests and young overstocked stands of ponderosa, sugar and western white pines.

Evidence of Attack

The first sign of beetle-caused mortality is generally discolored foliage. The mountain pine beetle begins attacking most pine species on the lower 15 feet of the bole. Examination of infested trees usually reveals the presence of pitch tubes. Pitch tubes on successfully infested trees are pink to dark red masses of resin mixed with boring dust. Creamy, white pitch tubes indicate that the tree was able to "pitch out" the beetle and the attack was not successful. In addition to pitch tubes, successfully infested trees will have dry boring dust in the bark crevices and around the base of the tree. Attacking beetles carry the spores of blue-staining fungi which develop and spread throughout the sapwood interrupting the flow of water to the crown. The fungi also reduces the flow of pitch in the tree, thus aiding the beetles in overcoming the tree. The combined action of both beetles and fungi causes the needles to discolor and the tree to die.

Life Stages and Development

The beetle develops through four stages: egg, larva, pupa and adult. The life cycle of the mountain pine beetle varies considerably over its range. One generation per year is typical, with attacks occurring from late June through August. Two generations per year may develop in low elevation sugar pine. Females making their first attacks release aggregating pheromones. These pheromones attract males and other females until a mass attack overcomes the tree. The adults bore long, vertical, egg galleries and lay eggs in niches along the sides of the gallery. The larvae feed in mines perpendicular to the main gallery and construct small pupal cells at the end of these mines where they pupate and transform into adults.

Conditions Affecting Outbreaks

The food supply regulates populations of the beetle. In lodgepole pine, it appears that the beetles select larger trees with thick phloem, however the relationship between beetle populations and phloem thickness in other hosts has not been established. A copious pitch flow from the pines can prevent successful attack. The number of beetles, the characteristics of the tree, and the weather affect the tree's ability to produce enough resin to resist attack. Other factors affecting the abundance of the mountain pine beetle include nematodes, woodpeckers, and predaceous and parasitic insects. As stand susceptibility to the beetle increases because of age, overstocking, diseases or drought, the effectiveness of natural control decreases and pine mortality increases.

Flatheaded Fir Borer

Flatheaded fir borers commonly breed in felled trees or those weakened by fire, defoliation, drought, or other types of disturbance. Trees infested are usually pole size or larger. Beetles can infest the entire tree or attacks can be confined to the upper crown and result in top kill. Flatheaded fir borers are considered less aggressive in their attacks on living trees than bark beetles. This beetle can be particularly aggressive on Douglas-fir growing on the edge of stands or scattered patches of trees on dry sites.

Detection of flatheaded fir borer attacks prior to the yellowing of the tree’s crown is difficult. Unlike bark beetles, there are typically no external indicators of attack such as boring dust or pitch streams on the bark. For this reason, infestations are rarely diagnosed before the damage has already occurred. However, it is sometimes possible to identify infested green trees during

the fall and winter months from the patches of bark removed by woodpeckers searching for beetle larvae. By the time the infested tree's foliage turns red, usually in the late spring or early summer in the year after attack, beetles have already left the tree. The only way to confirm a beetle attack is to remove a piece of bark and look for its distinctive gallery pattern. Larvae construct wide, winding galleries that increase in width as larvae grow. Galleries are filled with a brown dust packed in concentric lines. The removal of bark from the tree's lower bole does not guarantee detection of a flatheaded borer attack, since sometimes attacks are confined to the upper crown.

Although called a borer, the larvae of this large beetle feed and develop in the phloem/cambium interface, much like bark beetle larvae, and never bore into the tree's sapwood. The life cycle of the flatheaded fir borer normally requires one year. Adults emerge in the spring and feed on conifer needles before flying to a suitable host tree. Adult beetles can sometimes be seen resting on tree bark exposed to direct sunlight. Eggs are laid in bark crevices and upon hatching; larvae immediately bore into the inner bark. Larvae feed in the inner bark without boring into the sapwood. Late in the summer or early fall, larvae construct pupal cells in the outer bark. Winter is spent in the outer bark and adult beetles emerge the following spring.

Heterobasidion Root Disease

Heterobasidion spp. is a fungus that attacks a wide variety of woody plants. All western conifer species are susceptible. Madrone (*Arbutus menziesii*), and a few brush species (*Arctostaphylos spp.* and *Artemisia tridentata*) are occasional hosts. Other hardwood species are apparently not infected. The disease has been reported on all National Forests in California, with incidence particularly high on true fir in northern California, in the eastside pine type forests, and in southern California recreation areas.

Heterobasidion root disease is one of the most important conifer diseases in Region 5. Current estimates are that the disease infests about 2 million acres of commercial forestland in California, resulting in an annual volume loss of 19 million cubic feet. Other potential impacts of the disease include: increased susceptibility of infected trees to attack by bark beetles, mortality of infected trees presently on the site, the loss of the site for future production, and depletion of vegetative cover and increased probability of tree failure and hazard in recreation areas.

During periods favorable to the fungus, fruiting bodies (conks) form in decayed stumps, under the bark of dead trees, or under the duff at the root collar. New infection centers are initiated when airborne spores produced by the conks land and grow on freshly cut stump surfaces. Infection in true fir may also occur through fire and mechanical wounds, or occasionally, through roots of stumps in the absence of surface colonization. From the infected stump surface, the fungus grows down into the roots and then spreads via root-to-root contact to adjacent live trees, resulting in the formation of large disease centers. These infection centers may continue to enlarge until they reach barriers, such as openings in the stand or groups of resistant plants. In pines, the fungus grows through root cambial tissue to the root crown where it girdles and kills the tree. In true fir and other non-resinous species, the fungus sometimes kills trees, but more frequently is confined to the heartwood and inner sapwood of the larger roots. It then eventually extends into the heartwood of the lower trunk and causes chronic decay and growth loss.

Heterobasidion root disease in western North America is caused by two species: *Heterobasidion occidentale* (also called the 'S' type) and *H. irregulare* (also called the 'P' type). These two species of *Heterobasidion* have major differences in host specificity. *H. irregulare* ('P' type) is pathogenic on ponderosa pine, Jeffrey pine, sugar pine, Coulter pine, incense cedar, western juniper, pinyon, and manzanita. *H. occidentale* ('S' type) is pathogenic on true fir, spruce and giant sequoia. This host specificity is not apparent in isolates from stumps; with *H. occidentale* being recovered from both pine and true fir stumps. These data suggest that infection of host trees is specific, but saprophytic colonization of stumps is not. The fungus may survive in infected roots or stumps for many years. Young conifers established near these stumps often die shortly after their roots contact infected roots in the soil.

Dwarf mistletoe

Dwarf mistletoes (*Arceuthobium* spp.) are parasitic, flowering plants that can only survive on living conifers in the Pinaceae. They obtain most of their nutrients and all of their water and minerals from their hosts.

Dwarf mistletoes spread by means of seed. In the fall the fruit ripen and fall from the aerial shoots. The seeds are forcibly discharged. The seed is covered with a sticky substance and adheres to whatever it contacts. When a seed lands in a host tree crown, it usually sticks to a needle or twig, where it remains throughout the winter. The following spring the seed germinates and penetrates the twig at the base of the needle. For the next 2-4 years, the parasite grows within the host tissues, developing a root-like system within the inner bark and outer sapwood, and causing the twig or branch to swell. Aerial shoots then develop and bear seed in another 2-4 years.

Dispersal of dwarf mistletoe seeds is limited to the distance the seeds travel after being discharged. From overstory to understory, this is usually 20 to 60 feet, but wind may carry them as far as 100 feet from the source. A rule of thumb is that the seeds can travel a horizontal distance equal to the height of the highest plant in an infected tree. There is some evidence that long distance spread of dwarf mistletoe is occassionaly vectored by birds and animals.

Vertical spread within tree crowns of most dwarf mistletoes is limited to less than one foot per year because of foliage density. Because of the thin crowns of gray pine, however, the vertical rate of spread has been measured as being greater than 2 feet per year. This rate of spread equalled or exceeded the rate of height growth of infected trees.

Dwarf mistletoes are easy to identify because they are generally exposed to view within a tree's crown. Signs of infection include the yellow-green to orange mistletoe plants, basal cups on a branch or stem where the plants were attached and detached plants on the ground beneath an infected tree. Symptoms include spindle-shaped branch swellings, witches' brooms in the lower crown, and bole swellings.

White pine blister rust

White pine blister rust is caused by *Cronartium ribicola* an obligate parasite that attacks 5-needled pines and several species of *Ribes* spp. The fungus needs the two alternate hosts to survive, spending part of its life on 5-needled pines and the other on *Ribes* spp. The disease occurs throughout the range of sugar pine to the southern Sierra Nevada, but has not been reported further south. Infection of pines results in cankers on branches and main stems, branch mortality, top kill, and tree mortality.

Spores (aeciospores) produced by the fungus in the spring on pine bole or branch cankers are wind-disseminated to *Ribes* spp. where they infect the leaves. Spores (urediospores) produced in orange pustules on the underside of the leaves reinfect other *Ribes* spp. throughout the summer, resulting in an intensification of the rust. A telial spore stage forms on *Ribes* spp. leaves in the fall. Teliospores germinate in place to produce spores (sporida) which are wind-disseminated to pines and infect current year needles. Following infection, the fungus grows from the needle into the branch and forms a canker. After 2 or 3 years, spores are produced on the cankers and are spread to *Ribes* spp. to continue the cycle. Although blister rust may spread hundreds of miles from pines to *Ribes* spp., its spread from *Ribes* spp. back to pines is usually limited to a few hundred feet.

Branch cankers continue to enlarge as the fungus invades additional tissues and moves toward the bole. Branch cankers within 24 inches of the bole will eventually form bole cankers. Bole cankers result in girdling and death of the tree above the canker. Cankers that have margins more than 24 inches from the main bole are unlikely to reach the bole and only branch flagging will result.